original article

Accumulation of heavy metals in agricultural products irrigated with treated municipal wastewater

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ABSTRACT

Aims: The aim of this study was to measure the concentration of Pb, Cd, and Ni in the effluent of Isfahan north wastewater treatment plant as well as in the soils and agricultural products irrigated with that effluent.

Material and Methods: In the selected area around of the treatment plant, treated wastewater, soil, wheat, wheat stem, and corn were sampled. The samples were digested with nitric acid procedure and analyzed with a flameless atomic absorption spectrometer.

Results: The results shows the average concentration of Pb, Cd, and Ni was 0.02, 0.006, and 0.062 mg/1 in the effluent; 13.9, 1.67, and 2.23 μg/g in the deep soil; 0.366, 1.02, and 0.79 μg/g in the wheat; 0.67, 0.86, and 1.32 μg/g in the wheat stem; and 6.37, 0.62, and 0.52 μg/g in the corn, respectively.

Conclusion: The average concentration of Pb, Cd, and Ni were less than the critical limits in the effluent (0.01, 0.2, and 5 mg/1) and the amounts were currently within the permitted range for soil (2-100, 10-1000, and 10-7 mg/g). In some farming lands, the amounts were beyond the permitted range for plants (1-10, 1-10, and 0.2-0.8 mg/g). There was a meaningful relationship between the average concentration of these metals and the kind of sample. In addition, the accumulation of heavy metals in all samples irrigated with wastewater was more compared to samples irrigated with groundwater. So irrigation of farmland with effluent should be monitored. Farmers in the area must be advised to grow shrubs with smaller roots rather than big-rooted plants like sugar beet.

Key words: Cd, crops, effluent, heavy metals, irrigation, Ni, Pb, wastewater

INTRODUCTION

For some reasons, these days it is becoming growingly customary to use effluent from the urban wastewater treatment plant in order to irrigate agricultural lands. This is in part because of the need for further agricultural products in the short run. Other reasons include shortage of clean water and relatively higher cost of synthetic fertilizers. Also, this way of irrigation helps discharge the effluent of wastewater treatment plants.[1] Today, there are thousands of such projects underway worldwide recycling wastewater in agriculture.[2] In fact, effluent is an important alternative for use in irrigation.[1] With good management, this way of irrigation can lead to better yield for farmers. But we must be aware of all the hygienic and environmental issues concerning this technique. The quality of the wastewater

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used in irrigation concerns workers in contact with it as well as the agricultural products and human or animal consumers alike. Currently, there are worries regarding chemical contamination of agricultural products irrigated effluent from treatment plants.[3] Heavy metals like Pb, Hg, and Cd constitute the gravest example of this contamination.[2]

These metals are found not only in industrial wastewater but also in domestic sewage. Therefore, it is needed for monitoring the concentration of these metals in the effluent of wastewater treatment plants. Heavy metals in wastewater are transferred to the soil through irrigation and then they react with the components of the soil and accumulate there. The accumulation of heavy metals depends on the cation exchange capacity (CEC) of the soil.[3] In Table 1, we show the amount of this accumulation based on the CEC of the soil.[3] The composition of the soil and its pH can be affected on the heavy metal's detention time in the soil. Therefore, it is possible to stop the cycle of heavy metals in the soil by manipulating its composition. For example, through alkalinizing the soil, we can reduce its absorbability of heavy metals. Otherwise, by irrigating the soil with effluent or sewage of wastewater, heavy metals enter into the cycle of plants, animals, and humans. Eventually they accumulate in the body of humans and animals until they reach toxic levels.[3] Heavy metals have a tendency to accumulate in the soil. Furthermore, it is difficult to wash them out of the soil once they accumulate there.[4] Therefore, irrigation of farmland with effluent should be monitored concerning the fact that heavy metals are potentially toxic.[3] Table 2 shows the normal level of different heavy metals in the soil and plant tissue (μg/g) and their effect on plant growth.[3]

This investigation aimed to study the accumulation of Pb, Cd, and Ni in the soil and agricultural products irrigated with the effluent of wastewater treatment plants in north Isfahan. The research was carried out on farming lands around a treatment plant with a capacity of 650-700 l/s wastewater from the northern and some southern parts of the city. After primary treatment through the activated sludge method, the effluent of wastewater is used to irrigate nearby farmlands. Currently, the effluent from this plant covers the irrigation need for about 300 hectare of land in the region. Wheat, corn, and sugar beet are the main agricultural products of the region. Therefore, in this research, we studied wheat and corn.

MATERIALS AND METHODS

Five farms were randomly selected for each plant. Four samples from plants, surface, and deep (30 cm) soils were taken from each farmland. A composite sample for each kind was prepared by mixing of four samples. The effluent samples were taken for 15 weeks (once every week). Afterward, the samples from plants and soil were taken to the laboratory and were digested with sulfuric acid and hydrogen peroxide.[5] Effluent samples were also digested with nitric and perchloric acid after a thickening process.[6] Pb and Cd were analyzed via a flameless atomic absorption spectrometer (AAS).[7] Ni was analyzed by a flamed atomic absorption spectrometer.[8]

Table 1: Time needed for heavy metals to reach a critical level through irrigation with wastewater[3]

Element	Usual concentration (mg/l)	Annual input ½ m/y	Permitted limit of concentration per unit of CFC in soil (kg/ha)			Time needed (year to reach the permitted limit for CFC		
		Water depth	>15	5-15	<5	>15	5-15	<5
Cd	0.005	0.06	20	10	5	333	167	82
Cu	0.1	1.2	500	250	125	4.6	2.8	104
Ni	0.02	0.24	5000	250	125	2083	1042	521
Zn	0.15	1.8	1000	500	250	556	278	139
Pb	0.05	0.6	2000	1000	500	3333	1667	833

Table 2: Normal level of different heavy metals in the soil and plant tissue (μg/g) and their effect on plant growth[3]

Element	Concentration in soil			Effect on plant growth
As	0.1-40	6	0.1-5	Not needed
B	2-200	10	5-30	Needed for many plant species
Be	1-40	6	-	Not needed, poisonous
Bi	-	-	-	Not needed, poisonous
Cd	0.01-7	0.06	0.2-0.8	Not needed, poisonous
Cr	5-3000	100	0.2-1	Not needed, poisonous
Co	1-40	8	0.05-0.15	Less than 0.2 ppm is needed
Cu	2-100	20	2-15	2-4 ppm is needed, and more than that is poisonous
Pb	2-200	10	-10	Not needed, a little poisonous
Mn	100-400	850	15-100	Needed, depending on the Fe: Mn ratio can be poisonous
Mo	0.2-5	2	1-100	Needed less than 0.1 ppm, a little poisonous
Ni	10-1000	40	1-10	Not needed, more than 50 ppm is poisonous
Se	0.1-2	0.5	0.02-2	Not needed, more than 50 ppm is poisonous
V	20-500	100	0.1-10	Needed for some algae, more than 10 ppm is poisonous
Zn	10-300	50	15-200	Needed, more than 200 ppm is poisonous

RESULTS

Data in Table 3 shows the average concentration of Pb, Cd, and Ni in soil, plants, and effluent samples. The average concentration of Pb, Cd, and Ni in effluent were 0.011, 0.004, 0.053 mg/l [Figure 1], in deep soil 13.9, 1.67, 2.23 μg/g, in wheat 0.366, 1.02, 0.79 μg/g, in wheat stem 1.67, 0.86, 1.32 μg/g, and in corn 6.37, 0.62, 0.52 μg/g, respectively [Figures 2-4].

DISCUSSION

Based on the results of the study mentioned in Table 3, on average, there were 0.011, 0.004, and 0.053 mg of Pb, Cd, and Ni mg/l, respectively, in the effluent. Considering the fact that industrial factories in the region commonly release their wastewater in the urban sewage system, it is not surprising to find those amounts of heavy metals in this study. However, the amounts are less than the permitted limit for the aforementioned metals 5.0, 0.2, and 0.01 mg/l for Pb, Ni, and Cd, respectively.[3] In surface soil samples taken from farmland irrigated with the effluent, there were 11.49, 1.87, and 1.88 mg/g of Pb, Ni, and Cd, respectively. The figures were 13.9, 1.67, and 2.23 mg/g of the heavy metals in deep soil samples. The amounts were for the time within the permitted range for soil (2-200, 0.01-7, and 1-1000 mg/g) for Pb, Ni, and Cd, respectively.[3] Of course these figures increase as irrigation with effluent continues over time. Study conducted by Premarathna *et al.*, on heavy metal concentration in crops and soils collected from intensively cultivated areas of Sri Lanka indicated that the mean values of the heavy metal concentrations in soils were 60, 21.0, 1.16 mg/kg, and also these metals in the plants were recorded as 8.0, 13.0, 0.59 mg/kg for Pb, Ni, and Cd, respectively.[9] The average concentration of Pb and Ni in wheat, wheat stem, and corn samples were 0.366, 1.67, 6.356 and 0.79, 1.32, 0.5 mg/g plants (dried weight), respectively. The amounts were at the time within the permitted range for Pb and Ni

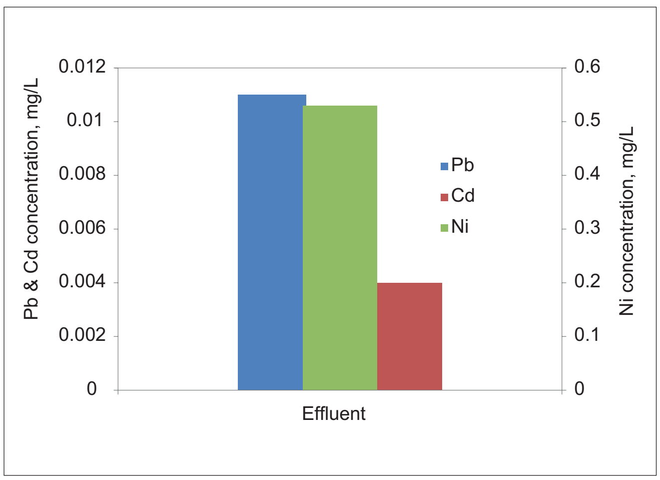

Figure 1: Average concentration of Pb, Cd, and Ni in effluent

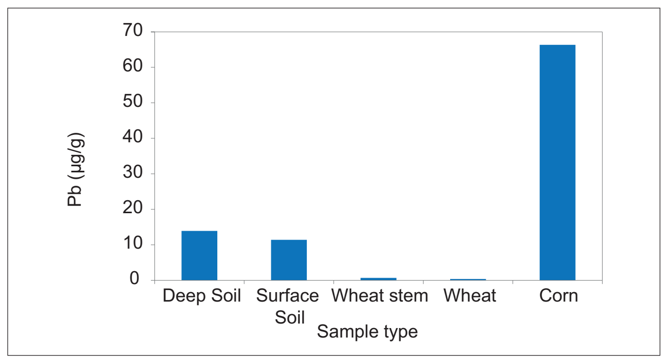

Figure 2: Average concentration of Pb in the soil and plant tissue

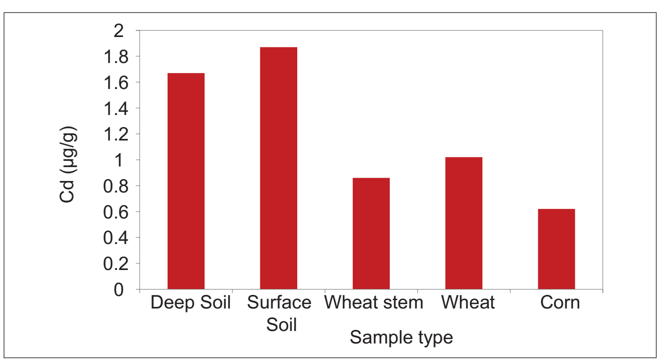

Figure 3: Average concentration of Cd in the soil and plant tissue

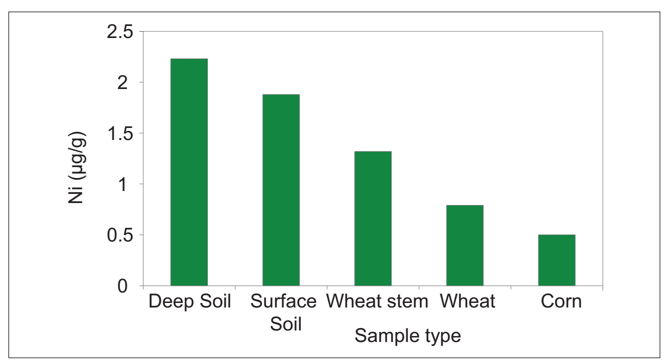

Figure 4: Average concentration of Ni in the soil and plant tissue

Table 3: Average concentrations of Pb, Cd, and Ni in the soil, plant tissue μg/g (dried weight) and effluent (mg/l)

Element	Wheat	Wheat stem	Corn	Surface soil	Deep soil	Effluent
	Min-Max (Avg.)					
Pb	0.24-0.4 (0.366)	0.87-2.28 (1.67)	4.6-8.13 (6.365)	0.83-22.20 (11.49)	1-17.4 (13.9)	0.800-0.02 (0.011)
Cd	0.53-1.6 (1.02)	0.71-1.12 (0.86)	0.38-0.86 (0.62)	1.6-2.7 (1.87)	1.11-2.4 (1.67)	0.800-0.006 (0.004)
Ni	0.35-1.97 (0.79)	1.26-1.46 (1.32	0.45-0.55 (0.5)	1.30-2.20 (1.88)	1.9-2.6 (2.23)	0.044-0.062 (0.053)

(0.1-10 and 1-10 mg/g) in plant tissue.[3] The results suggest that the agricultural products under the study are safe for consumption, but if irrigation with effluent continues, in the long run, more and more of these heavy metals accumulate in the agricultural products. Yadav *et al.*, showed that the contents of heavy metals in crops sampled from some parts of India irrigated with domestic sewage effluent were below the permissible critical levels. Though the study confirms that the domestic sewage can effectively increase water resource for irrigation, there is need for continuous monitoring of the concentrations of potentially toxic elements in the soil, plants, and ground water. Also heavy metals' concentration was improved considerably in sewage water irrigated soils and traces of Ni, Cd, and Pb were noticed in plants.[10] The average amount of Cd found in wheat and its stem were 1.021 and 0.86 mg/g (dried weight), respectively. The figures surpass the permitted levels 0.2-0.8 mg/g.[3] According to the study conducted by Binyham *et al.*, over the effect of Cd on the growth of different plant species, several products like tomato yielded up to 50% less when exposed to cadmium in soil.[11] Long-term consumption of these products can cause problems. Accumulation of these elements was not the same for different soil and plant samples. It means that the type of samples determines the degree of the accumulation of heavy metals. In other words, there is a meaningful relationship between the type of sample and the average concentration of heavy metals. Cd was mostly accumulated in surface soil while the least amount of the element was accumulated in wheat stem. However, Pb and Ni were mostly accumulated in deep soil samples. The least amount of the latter two elements was found in wheat. Therefore, it indicates that heavy metals' accumulation depends on the kind of sample (whether soil or plant). Also, a given sample like wheat acts selectively in accumulating two different elements. Secondly, we may understand that accumulation of different heavy metals varies in different layers of soil. He *et al.*, conducted a study (1992-1993) on the relationship between the kind of soil and its absorbability of cadmium. The results suggested that the type of soil used for agricultural purposes determines the degree of absorbability of heavy metals.[12] Results from the T-Hotelling test show there is a meaningful relationship between the concentration of Pb, Ni, and Cd in all of the samples from five farms, which were irrigated with effluent and the concentration of the heavy metals in the samples from farm 6, which was irrigated with groundwater. Sharma *et al.*, showed that the use of treated and untreated wastewater for irrigation has increased the contamination of Cd, Pb, and Ni in edible portion of vegetables causing potential health risk in the long term from this practice. The study also points to the fact that adherence to standards for heavy metal contamination of soil and irrigation water does not ensure safe food.[13]

With regard to the presence of heavy metals in the output wastewater in north Isfahan treatment plant, authorities are advised to prevent unauthorized streams of wastewater from joining the main urban sewage system. Considering the fact that the wastewater of the north Isfahan treatment plant is open for use by farmers in the region throughout the year and the fact that significant amounts of heavy metals were found in the soil and agricultural products grown in the farms, it is important to constantly monitor the amounts of these elements. Based on the results of this study about the presence of Pb, Ni, and Cd in the agricultural products grown in the region under the study, farmers in the area are advised to grow shrubs with smaller roots rather than big-rooted plants like sugar beet. Results from statistical analyses suggest that in similar studies, one should increase the number of samples over an extended period of time in order to reach more comprehensive results. Also, the cation exchange capacity (CEC) of soil changes over time. This leads to further accumulation of heavy metals in the soil. Therefore, the study should continue in the future.

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